

METHOD FOR CHECKING AT LEAST THREE SENSORS WHICH DETECT A  
MEASURED QUANTITY IN THE AREA OF AN INTERNAL COMBUSTION ENGINE

5 PRIORITY APPLICATION INFORMATION

The German priority applications nos. 102 49 344.8 and 103 41 454.1 are hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to a method for checking at  
10 least three sensors which detect a measured quantity in the  
area of an internal combustion engine.

BACKGROUND INFORMATION

To observe the limiting values of the exhaust gas in internal  
combustion engines, exhaust gas treatment systems are used  
15 which contain a catalytic converter, a particle filter or  
other components suitable for exhaust gas treatment, for  
example. The components used often operate in an optimum  
manner only in a certain temperature range. If the components  
have storage properties regarding at least one exhaust gas  
20 component, the laden state by the exhaust gas component must  
be monitored.

To detect the temperature as a measured quantity, temperature  
sensors are used, which may be situated in the intake area, on  
the internal combustion engine itself, or in the exhaust area.  
25 To detect pressure as a measured quantity, pressure sensors  
are used, which may be used to determine the laden state of a  
particle filter, for example. The pressure sensors detect the  
pressure difference occurring at the particle filter, which is

a measure of the laden state. Additional pressure sensors may be situated in the intake area of the internal combustion engine.

If a sensor delivers an erroneous signal, this may result in 5 erroneous control of the internal combustion engine and of the exhaust gas treatment system. The consequences include increased fuel consumption of the internal combustion engine and increased exhaust gas emissions.

Proper operation of the overall system is ensured only if the 10 sensors used deliver a reliable sensor signal. German patent document no. 101 12 139 discusses a method for monitoring sensors which detect a measured quantity of an internal combustion engine. These may include temperature sensors, pressure sensors or other sensors. The individual sensor 15 signals are compared to a reference signal delivered by an additional sensor, which is not involved in the diagnosis itself.

The sensor which is not involved in the diagnosis is situated at a point where there is a relatively light load on the 20 sensors such as the intake area in which a temperature sensor is exposed to less temperature fluctuations than it would be in the exhaust area. Defective sensors are detected by forming the difference between the individual sensor signals of the sensors to be monitored and the reference signal of the non- 25 monitored sensor and comparing it to the predefined threshold values. If no error is recognized in the preceding procedure steps, a plausibility check is finally performed by forming the differences between the signals of the sensors being monitored and comparing them to threshold values.

## SUMMARY OF THE INVENTION

An object of the present invention is to provide a method for checking at least three sensors which detect a measured quantity in the area of an internal combustion engine, which 5 delivers a reliable result while using simple monitoring means.

According to the method of the present invention, a measure for the sensor signal of the particular sensor to be checked is compared to a reference signal; the reference signal is 10 obtained from at least part of the sensor signals of the sensors to be checked; and a sensor is recognized as defective on the basis of a comparison of the measure for the sensor signal and the reference signal.

With the method according to the present invention, all 15 sensors are involved in the diagnosis. Another important advantage is that, when the check is based on checking at least three sensors, a defective sensor may be immediately recognized using simple comparison operations.

In one embodiment the reference signal is formed from an 20 average of a measure of the sensor signals of at least one part of the sensors to be checked. This procedure allows the reference signal to be provided in a very simple manner. In an advantageous refinement of this embodiment, each sensor signal is weighted using a predefined factor when forming the 25 average. Involving a weighting factor permits the importance and location of the individual sensors to be taken into account.

A simple check is made possible by a sensor being recognized as defective if the difference between the measure for the 30 sensor signal and the reference signal exceeds a predefined threshold value.

If the reference signal is distorted by at least one defective sensor, the embodiment in which the sensor whose measure for the sensor signal is farthest from the reference signal is recognized as defective still permits a defective sensor to be 5 reliably recognized.

In a refinement of the method according to the present invention, the check is performed in a steady-state operation or at a standstill or after a cold start of the internal combustion engine. The refinement ensures that the sensor 10 signals of the at least three sensors to be checked have an at least approximately constant value, so that the check yields a reliable result. At standstill or after a cold start of the internal combustion engine, the sensor signals have a value which is defined by the environmental conditions. Sensor 15 signals of temperature sensors largely reflect the temperature of the environment.

The measure of detecting the standstill of the internal combustion engine, a timer being provided which is started when standstill is detected, and performing the check after 20 the elapse of a predefined time period ensures that the sensor signals are actually steady when the internal combustion engine is at standstill.

Another measure which ensures that the steady-state operation, the standstill, or the cold start of the internal combustion 25 engine exists provides for a comparison between a sensor signal of at least one selected sensor which has a slow rate of change and a sensor signal of a sensor to be checked. The selected sensor is situated on a component which has the greatest possible inertia with respect to the sensor signal. 30 In the case of a temperature sensor, this is a component having a high heat capacity.

In a refinement of the method according to the present invention, the sensor signal of a sensor recognized as defective is not taken into account when determining the reference signal. The exclusion of the defective sensor in further checks ensures that the reference signal is not distorted. In another measure, no check is performed if the number of sensors recognized as defective exceeds a predefined number.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a block diagram of an internal combustion engine and a controller.

Figure 2 shows a flow chart of an exemplary method according to the present invention.

Figure 3 shows a flow chart of another exemplary method according to the present invention.

Figure 4 shows a flow chart of another exemplary method according to the present invention.

Figure 5 shows a flow chart of another exemplary method according to the present invention.

#### DETAILED DESCRIPTION

Fresh air is supplied to internal combustion engine 100 via an intake area 105. The exhaust gases of internal combustion engine 100 pass through an exhaust gas area 110. An exhaust gas treatment system 115 is situated in exhaust gas area 110.

This may be a catalytic converter and/or a particle filter. Exhaust gas treatment system 115 may include a plurality of catalytic converters for different harmful substances, or combinations of at least one catalytic converter and a particle filter.

- Furthermore, a control unit 170 is provided, which contains at least one engine control unit 175 and one exhaust gas treatment control unit 172. Alternatively, engine control unit 175 and exhaust gas treatment control unit 172 may also be
- 5 situated separately. Engine control unit 175 supplies control signals to a fuel metering system 180. Furthermore, engine control unit 175 and/or exhaust gas treatment control unit 172 supply signals to one another and/or to additional control units.
- 10 Furthermore, sensors supplying signals to exhaust gas treatment control unit 172 and engine control unit 175 are provided. A first sensor 191 supplies a sensor signal S1 which characterizes the state of the fresh air. A second sensor 192 supplies a sensor signal S2 which characterizes the state of
- 15 fuel metering system 180. A third sensor 193 supplies a sensor signal S3 which characterizes the state of exhaust gas upstream from exhaust gas treatment system 115. A fourth sensor 194 supplies a sensor signal S4 which characterizes the state of exhaust gas treatment system 115. A fifth sensor 195 supplies a sensor signal S5 which characterizes the state of the exhaust gases downstream from exhaust gas treatment system 115. All five sensors 191, 192, 193, 194, 195 detect a single measured quantity in the area of internal combustion engine 100. The measured quantity is the temperature, for example.
- 20 Alternatively, the measured quantity may be the pressure. Other measured quantities, such as acceleration or rotational speed, are also conceivable.
- 25

Depending on the embodiment, all illustrated sensors 191, 192, 193, 194, 195 may be provided. In alternative embodiments, the

- 30 minimum number of three sensors or more than the illustrated five sensors 191, 192, 193, 194, 195 may be provided.

The method according to the present invention for checking at least three sensors 191, 192, 193, 194, 195 which detect a measured quantity in the area of internal combustion engine 100 works as follows:

- 5 On the basis of sensor signals S1, S2, S3, S4, S5, engine controller 175 computes a control signal to be supplied to fuel metering system 180. Fuel metering system 180 then meters the corresponding amount of fuel to internal combustion engine 100. The harmful exhaust gas components produced during
- 10 combustion are converted into harmless components in one or more catalytic converters contained in exhaust gas treatment system 115. Exhaust gas treatment system 115 may contain a particle filter to remove the particles contained in the exhaust gas. A catalytic converter operates in an optimum
- 15 manner in a certain temperature range. A particle filter is also regenerated in an optimum manner in a certain temperature range. Sensors 191, 192, 193, 194, 195 designed as temperature sensors detect the temperature at various points.

- The exhaust gas temperature of internal combustion engine 100
- 20 may be maintained at a predefined temperature level or in a predefined temperature range using these sensors 191, 192, 193, 194, 195. Sensors 191, 192, 193, 194, 195 designed as pressure sensors determine the pressures occurring in intake area 105, at internal combustion engine 100, and/or in exhaust
  - 25 area 110. For example, the laden state of the particle filter may be determined on the basis of the occurring pressure difference. First sensor 191 situated in intake area 105 detects, for example, the air pressure which may be taken into account when determining the air-fuel mixture.
  - 30 Checking the proper operation of the at least three sensors 191, 192, 193, 194, 195 ensures the proper operation of

internal combustion engine 100 and in particular of exhaust gas treatment system 115.

Figure 2 shows a further embodiment according to the present invention on the basis of a flow chart. A first query 200 5 checks whether there are operating states in which a check is possible. Such operating states exist in particular when internal combustion engine 100 is in a steady-state operation, when internal combustion engine 100 is shut off and is at a standstill, or when engine 100 has just been started and is 10 still in the cold start phase.

In an advantageous embodiment, the standstill of internal combustion engine 100 is detected. For this purpose, a provided timer outputs a signal after the elapse of a predefined period of time; when this occurs, it may be assumed 15 that a sufficiently long standstill of internal combustion engine 100 has occurred. If internal combustion engine 100 is started after a sufficiently long standstill, a cold start may be assumed.

In an advantageous embodiment which detects a steady-state 20 operation, the standstill, and/or the cold start of internal combustion engine 100, sensor signal S1, S2, S3, S4, S5 of a selected sensor 191, 192, 193, 194, 195 which has a slow rate of change is compared to sensor signal S1, S2, S3, S4, S5 of at least one other sensor 191, 192, 193, 194, 195. If sensors 25 191, 192, 193, 194, 195 are temperature sensors, the sensor signal of sensor 191, 192, 193, 194, 195 which detects the temperature of the medium having the greatest heat capacity is used. In the illustrated exemplary embodiment, this is preferably second sensor 192, which detects the temperature of 30 fuel metering system 180. In this embodiment it is determined that the entire system is in a state of equilibrium, which occurs in a steady-state operation, at the standstill, or at a

cold start of internal combustion engine 100. It is irrelevant whether sensor 191, 192, 193, 194, 195 itself or the medium whose temperature is being detected has a high heat capacity. A steady-state operation, a standstill, or a cold start of 5 internal combustion engine 100 exists when the difference between the sensor signal of selected sensor 191, 192, 193, 194, 195 and the at least one other sensor 191, 192, 193, 194, 195 is less than a predefined threshold value.

In a refinement of this embodiment, the sensor signals of two 10 selected sensors 191, 192, 193, 194, 195 which have a slow rate of change are used for the comparison. In this case it is sufficient if at least one difference meets the criterion.

After it has been established in first query 200 whether such an operating state exists, a mean value  $M$  of a measure of 15 sensor signals  $S_1, S_2, S_3, S_4, S_5$  of sensors 191, 192, 193, 194, 195 to be checked is formed in a first function block 210. In this exemplary embodiment mean value  $M$  is the reference signal. Individual sensor signals  $S_1, S_2, S_3, S_4, S_5$  are preferably weighted when forming the mean value. 20 Correction factors  $K_1, K_2, K_3, K_4, K_5$  are used for weighting. Weighting makes it possible to take into account the importance of individual sensors 191, 192, 193, 194, 195 and/or their locations.

An important advantage results from the fact that the 25 weighting of those sensors 191, 192, 193, 194, 195 which, in a steady-state operation, at a standstill, or during a cold start of internal combustion engine 100, deliver different sensor signals depending on the environmental conditions may be reduced. It may occur, for example, that first sensor 191 30 detects different temperatures under sunny conditions than under cloudy conditions at the same ambient temperature if internal combustion engine 100 is situated in a motor vehicle.

- Even in this case, a steady-state operation, a standstill, or a cold start of internal combustion engine 100 is present in which a check of sensors 191, 192, 193, 194, 195 according to the present invention is enabled.
- 5 In a subsequent second function block 220, differences  $D_n$  of individual sensor signals  $S_n$  with respect to mean value  $M$  determined in first function block 210 are determined. In a second query 230, individual differences  $D_n$  are compared to a threshold value  $SW$ . The particular difference  $D_n$  which exceeds 10 threshold value  $SW$  indicates sensor 191, 192, 193, 194, 195 which is probably defective.

Figure 3 shows an alternative embodiment. Differences  $D_n$  between individual sensor signals  $S_n$  and mean value  $M$  are determined again in second function block 220. In a subsequent 15 third function block 240, maximum difference  $\text{Max } D_n$  is determined. In subsequent third query 250 a check is performed to determine whether determined maximum difference  $\text{Max } D_n$  exceeds a predefined threshold value  $SW$ . If this is the case, this sensor 191, 192, 193, 194, 195 having the maximum 20 difference is probably defective. The advantage of this alternative embodiment is that a defective sensor 191, 192, 193, 194, 195 whose sensor signal  $S_1, S_2, S_3, S_4, S_5$  may distort mean value  $M$  determined in function block 210 does not result in too many sensors 191, 192, 193, 194, 195 being 25 erroneously classified as defective in the check of second query 230.

Figure 4 shows another alternative embodiment. In this embodiment, the reference signal is obtained from a measure of a sensor signal  $S_1, S_2, S_3, S_4, S_5$  of a single sensor 191, 30 192, 193, 194, 195 to be checked. In the simplest case, the reference signal is identical to sensor signal  $S_1, S_2, S_3, S_4, S_5$ . This case is shown in Figure 4. Furthermore, for reasons

of clarity, the exemplary embodiment according to Figure 4 is limited to three sensors 191, 192, 193.

First query 200, described above, detects whether an operating state of internal combustion engine 100 exists in which monitoring is allowed. If this is the case, a first difference D1 between sensor signal S1 of first sensor 191 and sensor signal S2 of second sensor 192 is determined in function block 510. In subsequent function block 520, a second difference D2 between sensor signal S1 of first sensor 191 and sensor signal S3 of third sensor 193 is determined.

Subsequent query 530 checks whether first difference D1 is greater than a first threshold value SW1. If this is the case, an additional query 540 checks whether second difference D2 is greater than a second threshold value SW2. If this is not the case, first sensor S1 is recognized as defective in a function block 560. If it is determined in query 540 that second difference D2 is greater than second threshold value SW2, second sensor S2 is recognized as defective in a function block 262.

If it is determined in query 530 that first difference D1 is not greater than first threshold value SW1, a query 550 checks whether second difference D2 is greater than second threshold value SW2. If this is the case, third sensor S3 is recognized as defective in a function block 264. If differences D1, D2 are less than threshold values SW1 and SW2, function block 266 determines that no error is present.

Threshold values SW1 and SW2 have preferably the same value. However, threshold values SW1 and SW2 may also have different values.

Figure 5 shows another exemplary embodiment. In this embodiment, the reference signal is also obtained from a

measure of a sensor signal S1, S2, S3, S4, S5 of a single sensor 191, 192, 193, 194, 195 to be checked. In the simplest case, the reference signal is identical to sensor signal S1, S2, S3, S4, S5. This case is shown in Figure 5. Furthermore, 5 for reasons of clarity, the exemplary embodiment according to Figure 5 is also limited to three sensors 191, 192, 193.

The difference between the exemplary embodiment of Figures 4 and 5 is that in the exemplary embodiment of Figure 5, differences D1, D2, D3 are formed between all sensor signals 10 S1, S2, S3. The absolute value of the difference between individual sensor signals S1, S2, S3 is determined in each case. If all differences D1, D2, D3 are less than a threshold value SW1, all sensors 191, 192, 193 are recognized as error-free. If one of differences D1, D2, D3 is greater than 15 threshold value SW1, an error is recognized. However, the error cannot be assigned to a sensor 191, 192, 193. If two differences are greater than threshold value SW1, the particular sensor 191, 192, 193 that is used in both computations of the differences is recognized as defective. In 20 this embodiment, not only may an error be recognized, but it may also be assigned to a certain sensor 191, 192, 193.

In first query 200, as in the previous exemplary embodiments, a check is performed of whether a steady-state operation, a standstill, or a cold start of internal combustion engine 100 25 exists. In a next function block 410, a first difference D1 between first sensor signal S1 and second sensor signal S2 is formed. As in all the previously described difference formations, the absolute value of the difference is preferably formed also in this case. In a function block 420, a second 30 difference D2 is formed, representing the absolute value of the difference between first sensor signal S1 and third sensor signal S3. In a further function block 430, a third difference D3 is formed, representing the absolute value of the

difference between second sensor signal S2 and third sensor signal S3.

In subsequent query 440, a check is performed to determine whether difference D1 is greater than threshold value SW1. If 5 this is the case, a query 445 checks whether second difference D2 is greater than a second threshold value SW2. If this is the case, first sensor 191 is recognized as defective in a function block 260. If this is not the case, a query 448 checks whether third difference D3 is greater than a threshold 10 value SW3. If this is the case, second sensor 192 is recognized as defective in the function block. If this is not the case, an error which is not assignable is recognized in a function block 268.

If it is determined in query 440 that difference D1 is not 15 greater than first threshold value SW1, a query 450 checks whether second difference D2 is greater than second threshold value SW2. If this is not the case, error-free sensors 191, 192, 193 are recognized in function block 266. If this is the case, a query 455 checks whether third difference D3 is 20 greater than threshold value SW2. If this is the case, third sensor 193 is recognized as defective in a function block 264. If this is not the case, an error which is not assignable is recognized in a function block 268.